Blood Pressure Measurement: Continuous, Invasive Blood Pressure Monitoring

Authors and Disclosures

Continuous, Invasive Blood Pressure Monitoring

This is the gold standard of blood pressure measurement giving accurate beat-to-beat information. In general, systolic pressure will be slightly higher and diastolic pressure slightly lower (510 mm Hg), than non-invasive measurements. It is useful when rapid changes in blood pressure are anticipated (due to cardiovascular instability, large fluid shifts or pharmacological effects) or when non-invasive blood pressure monitoring is not possible or likely to be inaccurate (obesity, arrhythmias such as atrial fibrillation, non-pulsatile blood flow during cardiopulmonary bypass). It is also used when long-term measurement in sick patients is required as it avoids the problem of repeated cuff inflation (causing localized tissue damage) and allows repetitive sampling for blood gases and laboratory analysis.

Continuous invasive BP monitors display the information both numerically and graphically. The basic principle is to provide a solid column of liquid connecting arterial blood to a pressure transducer (hydraulic coupling) and requires the following components:

1. intra-arterial cannula;
2. tubing (incorporating an infusion system);
3. transducer;
4. microprocessor and display screen;
5. mechanism for zeroing and calibration.

Intra-Arterial Cannula. A short, parallel-sided cannula made of Teflon or polyurethane is inserted into an artery. Normally, a 20G cannula is used although 22G, and 25G are available for children and neonates. Preferably, a non-end artery, such as radial or dorsalis pedis is cannulated. Should thrombosis of the artery occur, arterial sufficiency is maintained via a collateral supply. The collateral supply to the hand can be assessed using Allen's test although this is not 100% reliable. If cannulation of those arteries is not possible, end arteries such as brachial or femoral may be used with due care to distal arterial sufficiency.

Infusion and Tubing. The cannula is connected to a disposable tubing system, which delivers a constant infusion of plain or heparinized 0.9% saline, delivered at a rate of 24 mls h^{-1}. This helps prevent occlusion of the cannula by thrombus. The infusion fluid is kept pressurized to ensure a constant flow into the arterial system. The tubing should be stiff and not contain any bubbles in order to minimize resonance and damping (see below).

Transducers. The liquid within the infusion tubing is in contact with a diaphragm that moves in response to the transmitted pressure waveform. The movement is converted to an electrical signal by a transducer. The transducer can do this by acting as part of a capacitor, inductor, or most commonly a strain gauge.

Strain gauges use the principle that resistance of a wire increases with increasing length and visa versa. The diaphragm of the transducer moves a small plate that is connected to four strain gauges. With any one movement, two gauges are compressed and the other two stretched. The material used in the strain gauge is important as different materials have different sensitivity to stress and strain and whose resistances will differ according to temperature. By using four gauges, two of which are compressed and two stretched, the effect of a change of temperature (so long as this remains linear) is cancelled out. All four strain gauges form part of a Wheatstone bridge thus increasing the sensitivity four-fold.

The transducer needs to be kept horizontally level with the patient; traditionally, the right atrium. Raising or lowering the transducer relative to the patient will alter the reading. A 10 cm change in height will alter the pressure reading by 7.5 mm Hg. NB if the cannula is inserted into the radial artery, raising the hand will not affect the measurement so long as the transducer is maintained level with the heart, unlike non-invasive methods.

Microprocessor and Display Screen. These provide a user-friendly numerical and graphical display allowing beat-to-beat measurement of pressure and also allow analysis of the waveform. Analysis can be clinical (e.g. morphology, determining the position of the dichrotic notch or 'swing' which can give information regarding filling status and cardiac output), or computerized. Systems such as the LiDCO and PICCO rely on such information in order to measure cardiac output.

Zeroing and Calibration. While being an important consideration, modern systems do not require calibration. Zeroing is still important and is performed by opening the transducer to atmospheric pressure and electronically zeroing the system.

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Cont Edu Anaesth Crit Care & Pain. 2007;7(4):122-126. © 2007 Oxford University Press

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